US009065178B2

(12) United States Patent
Gyenes

(10) Patent No.: US 9,065,178 B2
(45) Date of Patent: Jun. 23, 2015

(54) **RAPID TUNING FREQUENCY ADJUSTABLE MOBILE HF COMMUNICATION ANTENNA**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 423 days.

(21) Appl. No.: **13/602,261**

(22) Filed: **Sep. 3, 2012**

(65) **Prior Publication Data**

US 2014/0062814 A1 Mar. 6, 2014

(51) **Int. Cl.**

H01Q 9/00	(2006.01)
H01Q 9/30	(2006.01)
H01Q 1/36	(2006.01)
H01Q 21/30	(2006.01)
H01Q 1/32	(2006.01)

(52) **U.S. Cl.**

CPC ***H01Q 9/30*** (2013.01); *H01Q 1/3258* (2013.01); ***H01Q 1/36*** (2013.01); ***H01Q 21/30*** (2013.01)

(58) **Field of Classification Search**

USPC 343/702, 745

See application file for complete search history.

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(57) **ABSTRACT**

A mobile high-frequency antenna rapidly adjustable to minimize VSWR and maximize transmitting and receiving efficiency includes a conductive whip mounted on a coil housing containing a solenoidal loading coil electrically connected at an upper end to the whip and at a lower end to a conductive mast which supports the coil housing. A coil contactor disk at the upper end of a conductive metal shaft raised or lowered by a stepper motor-driven lead screw has protruding spring loaded balls which rollingly contact inner surfaces of coil turns to thus insert less or more inductance between the shaft and whip to tune the antenna. A pair of RF de-couplers in a coil housing base plug which electrically contacts the mast and the lower end of the coil slidably support and electrically contact the shaft, thus shorting out lower parts of the coil to suppress harmonic currents from being induced therein.

21 Claims, 12 Drawing Sheets

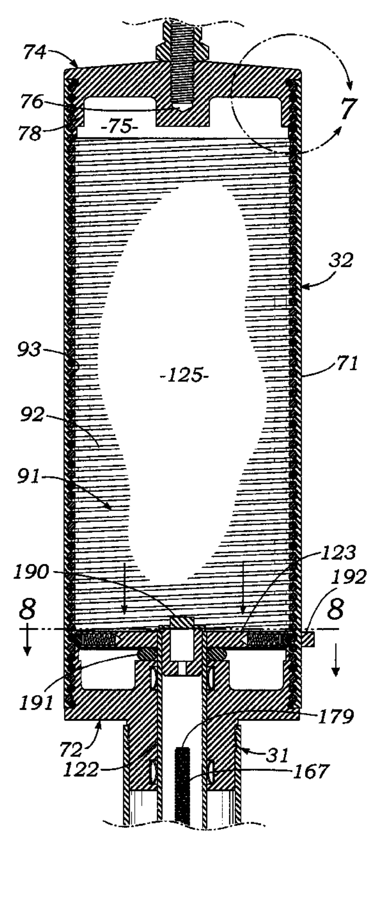

Fig. 1

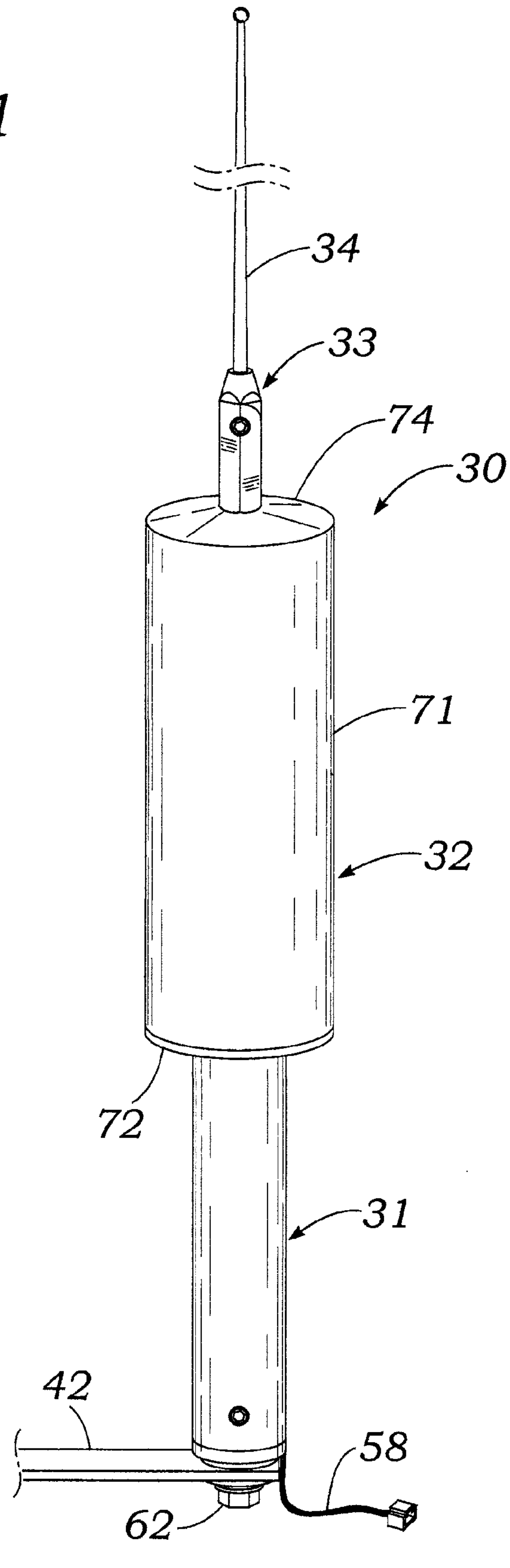

Fig. 2

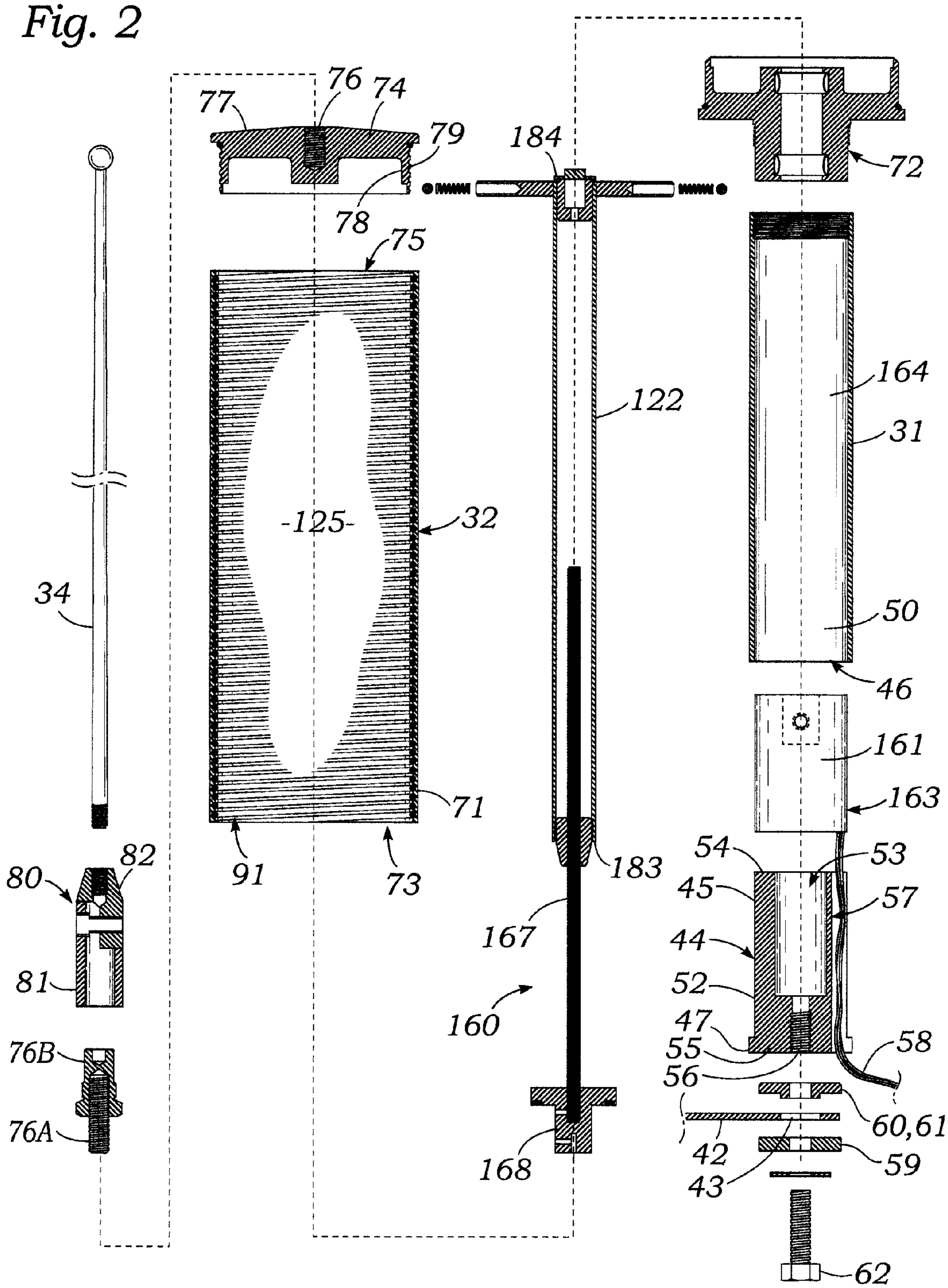
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Fig. 3

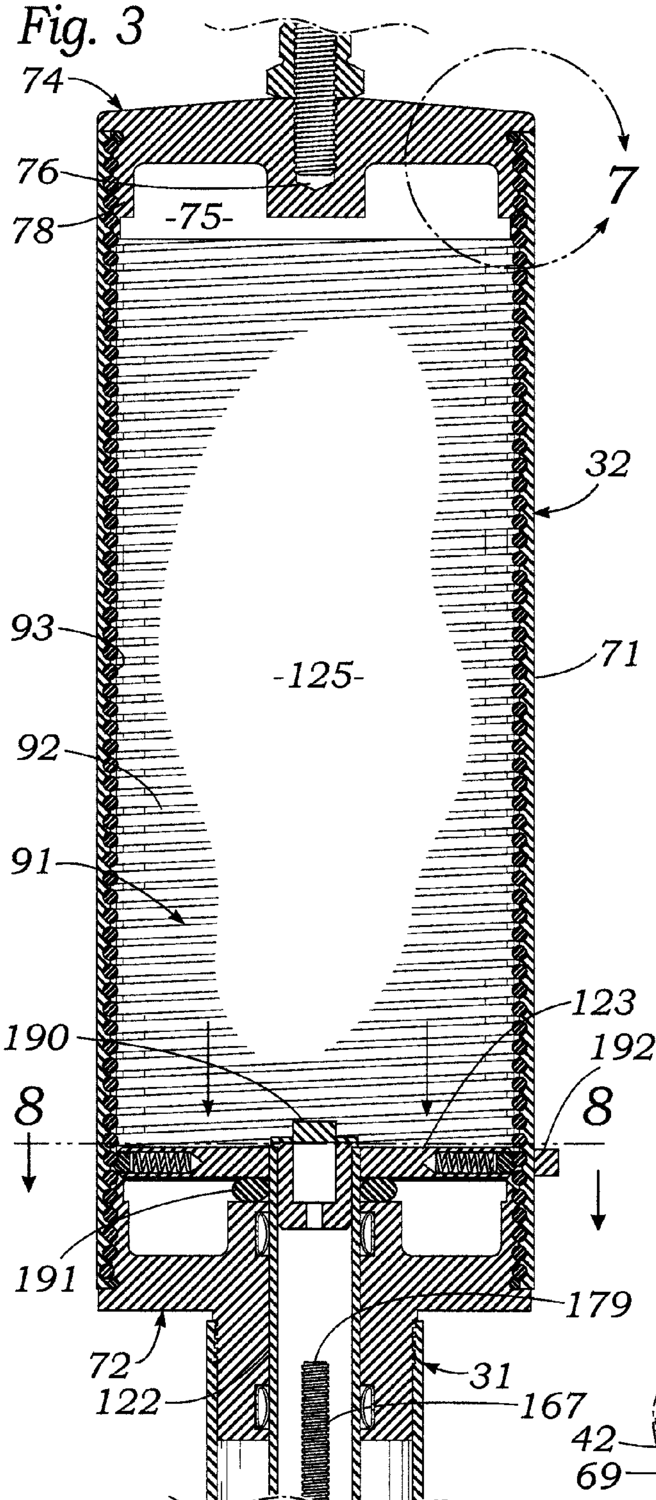
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Fig. 4

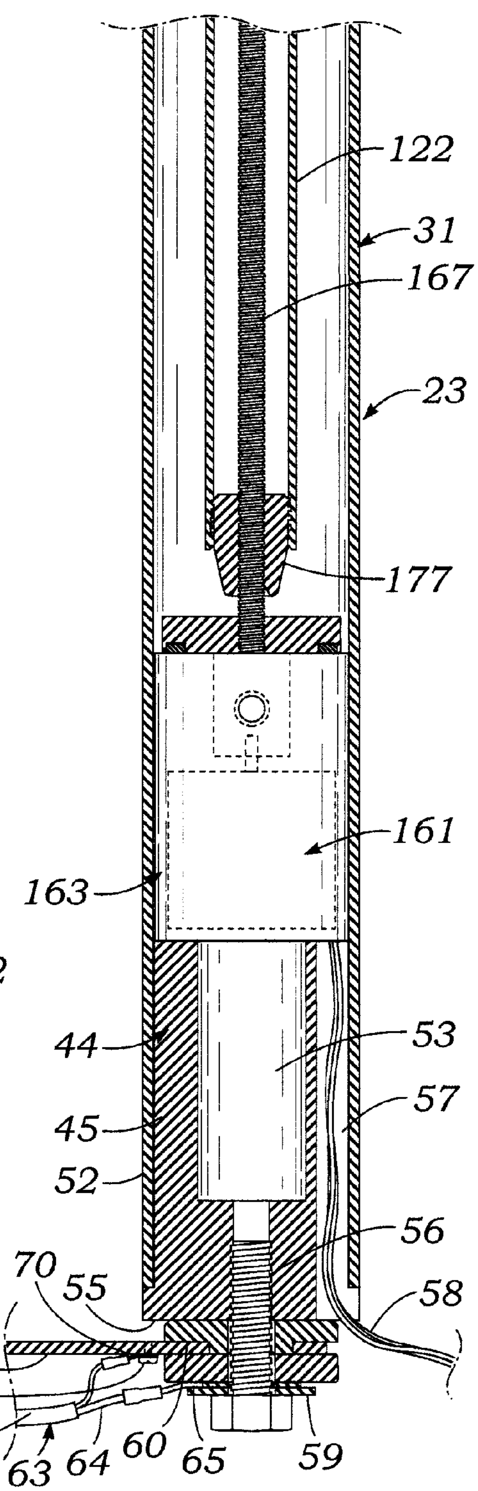
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Fig. 5

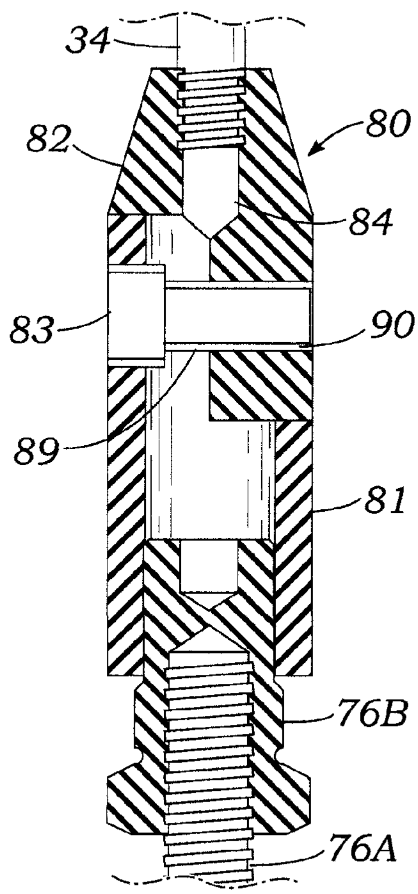

Fig. 7

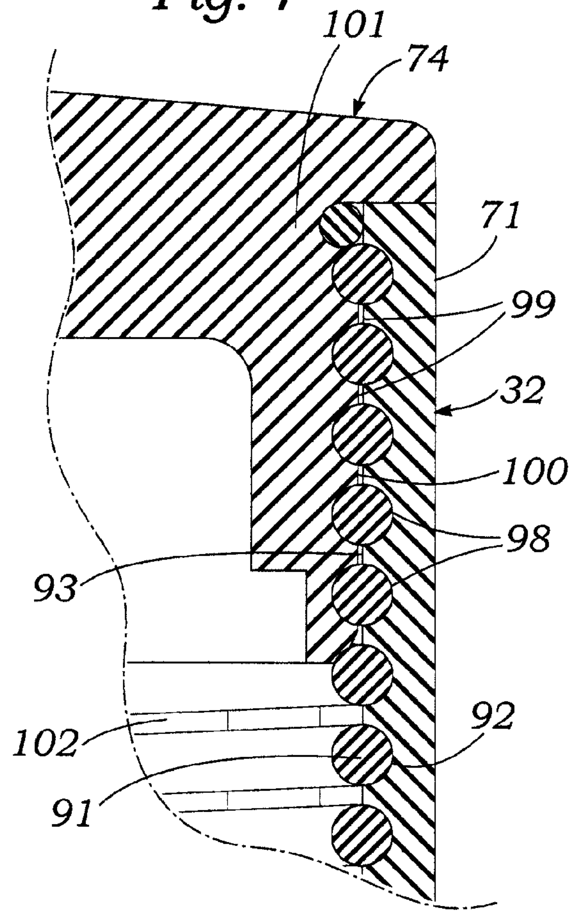

Fig. 18

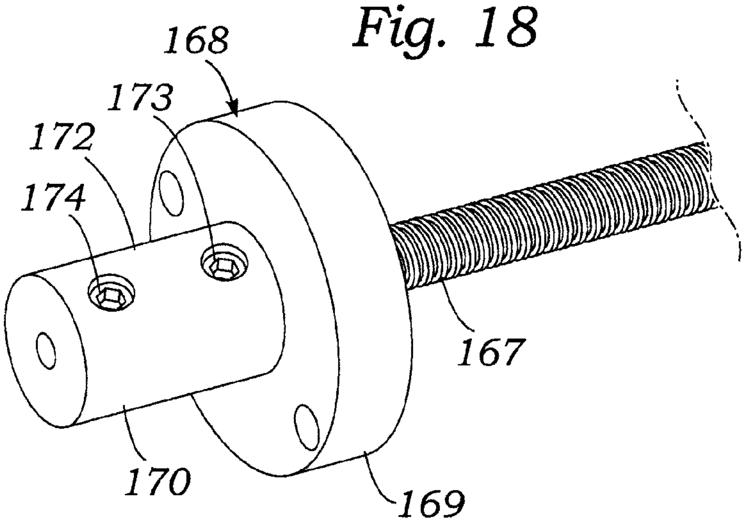

Fig. 6

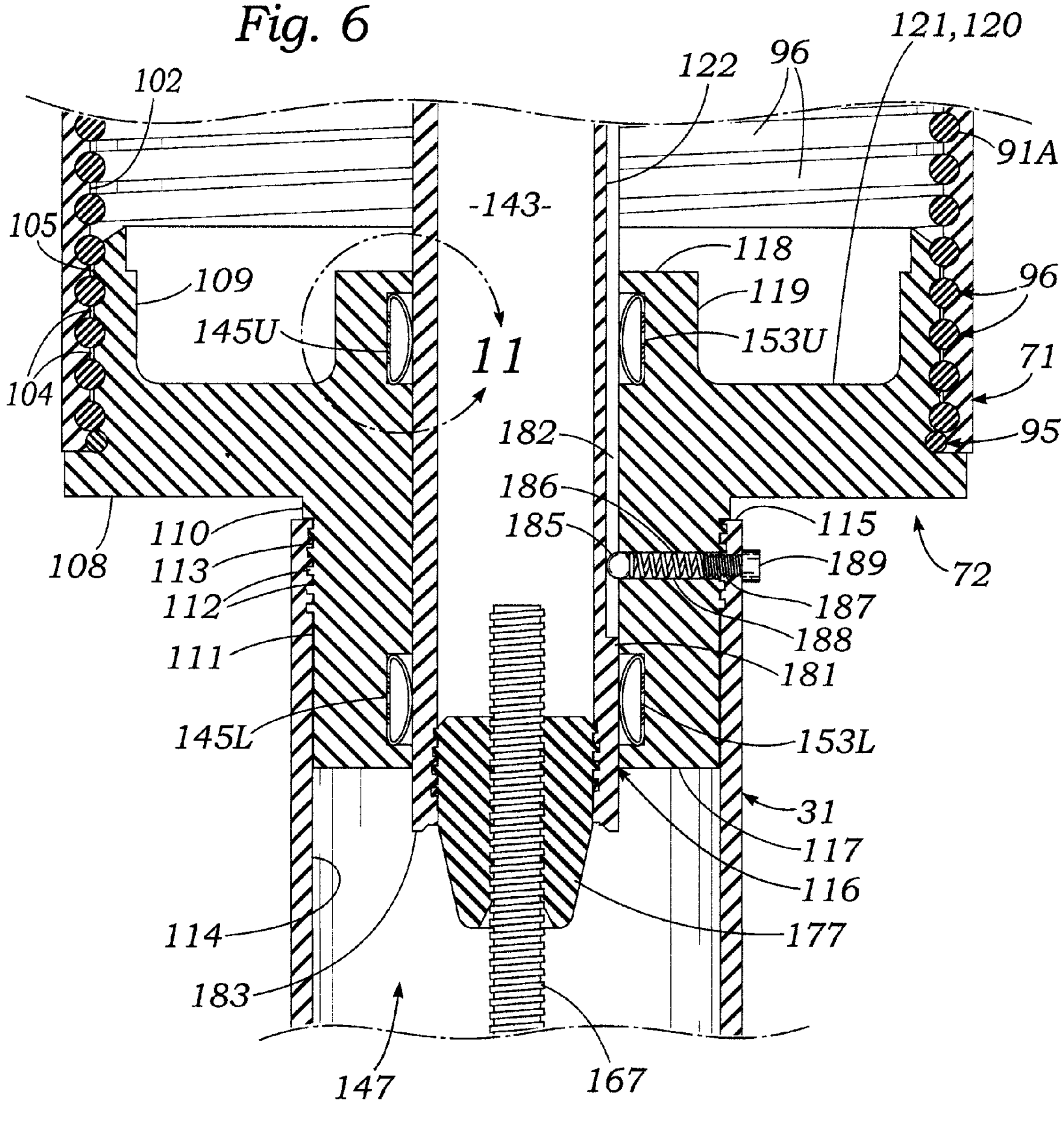
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Fig. 9

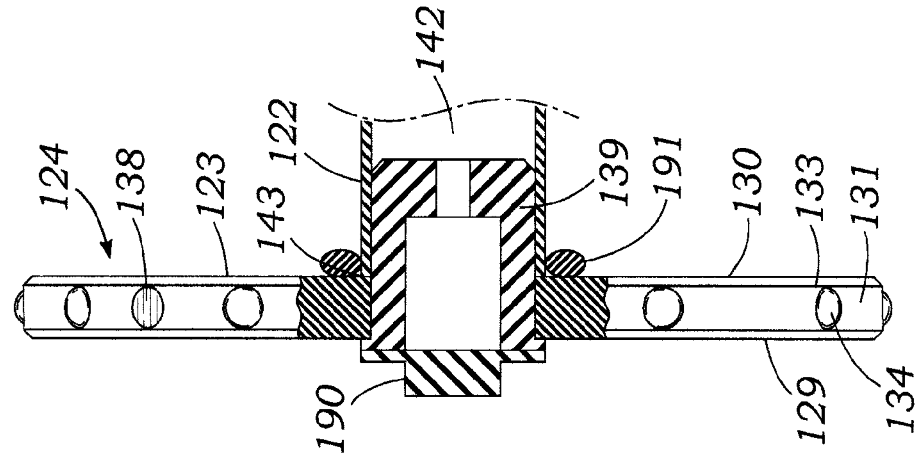
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Fig. 8

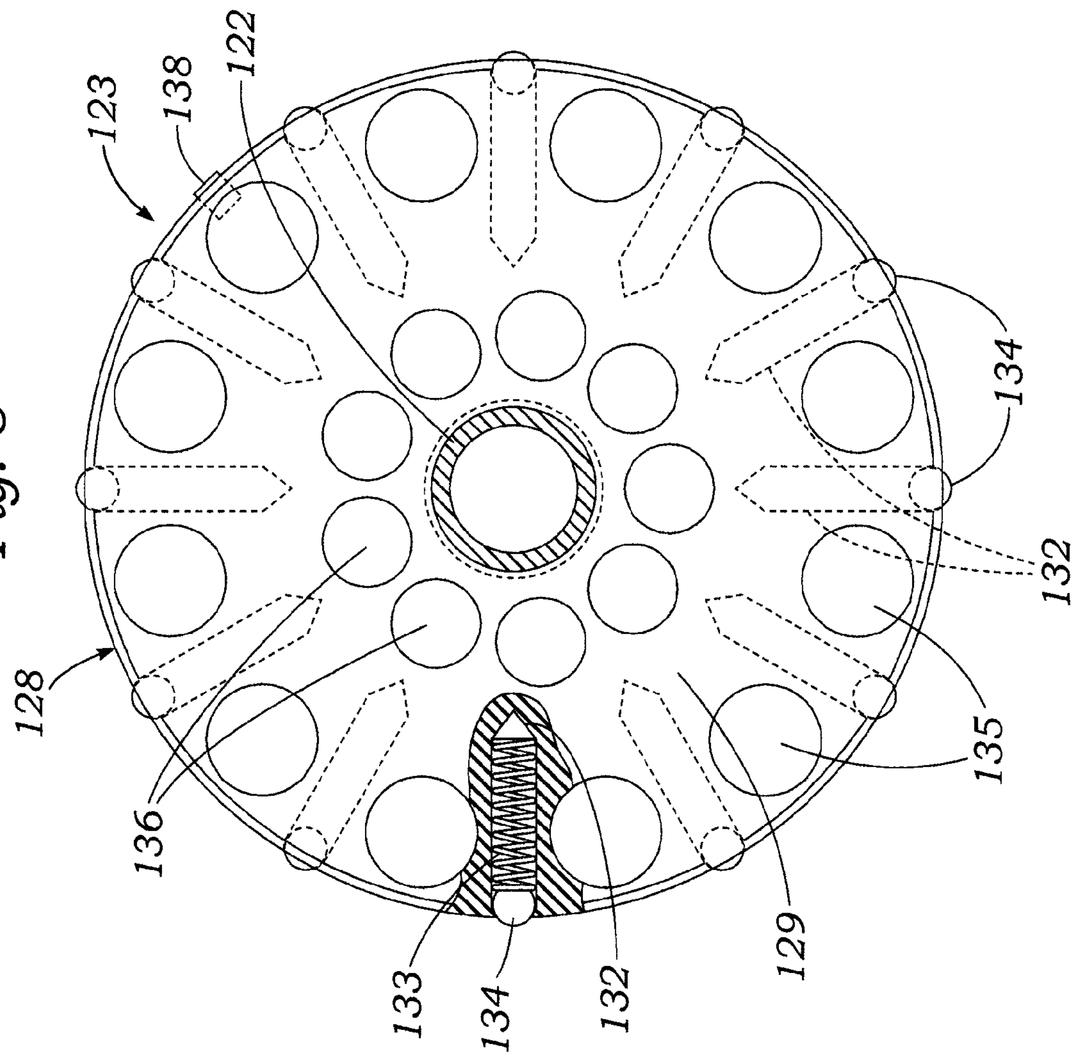
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Fig. 10

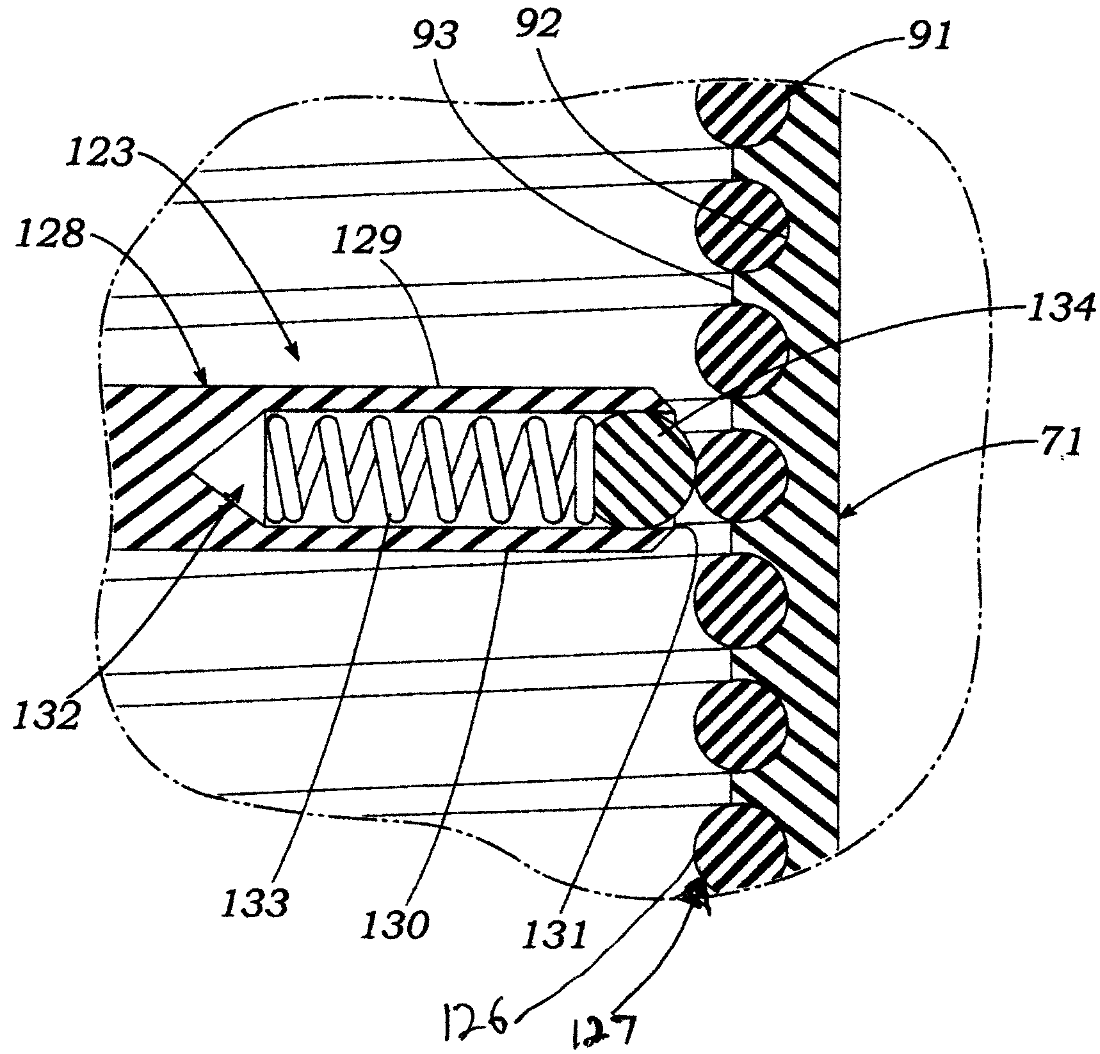


Fig. 12

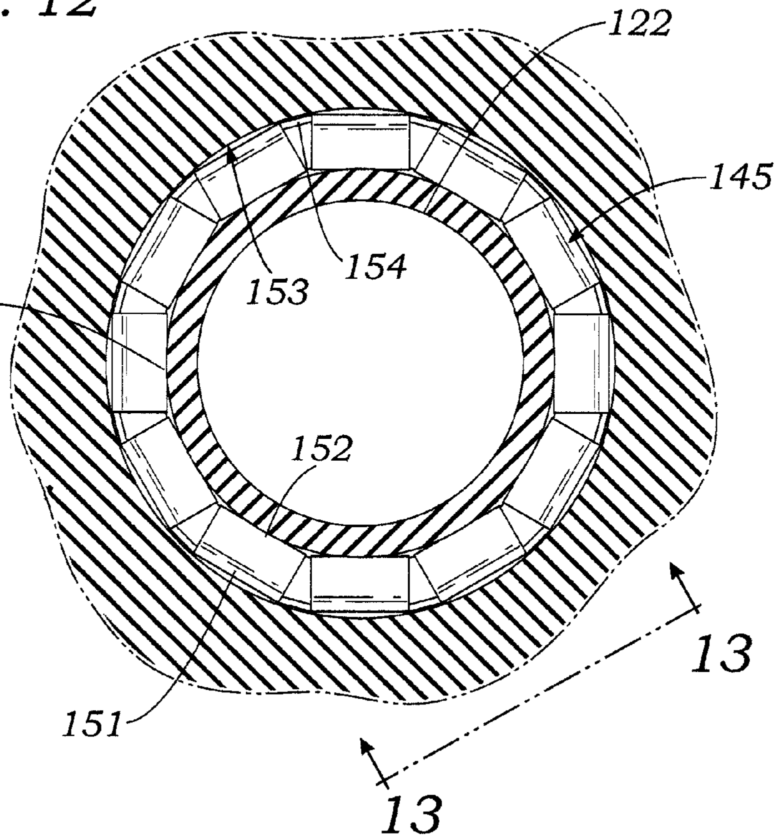


Fig. 11

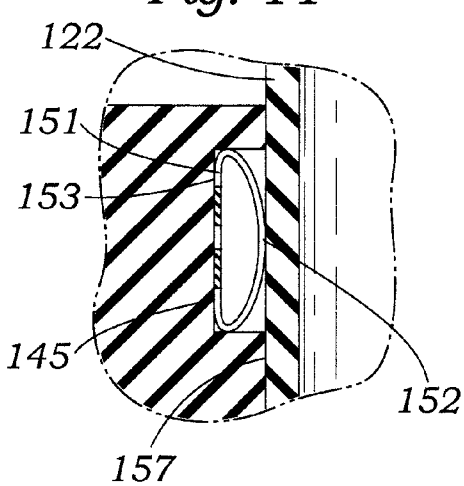


Fig. 13

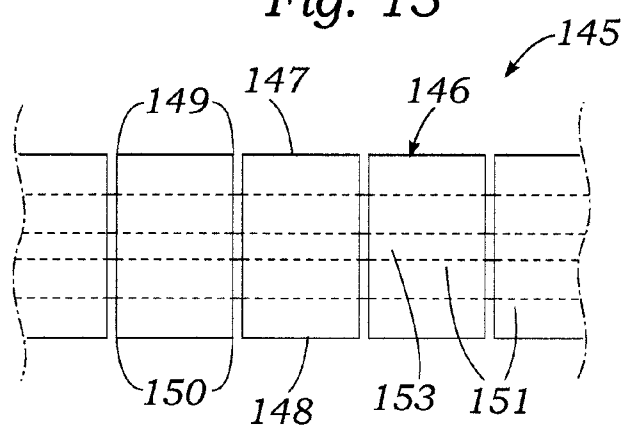


Fig. 14

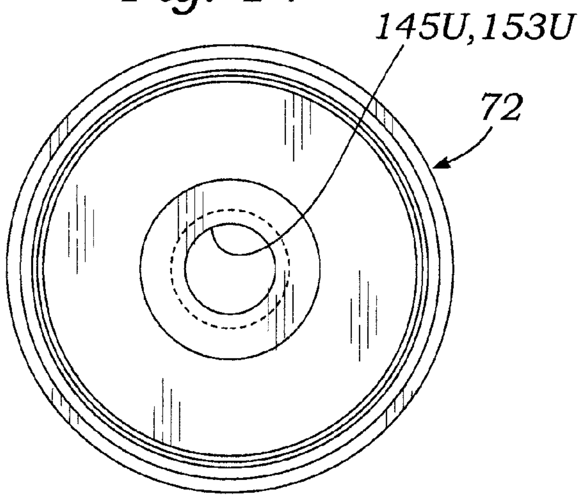


Fig. 17

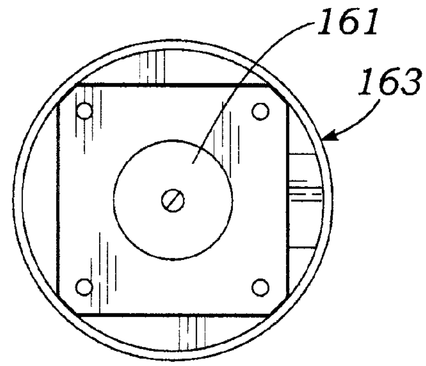
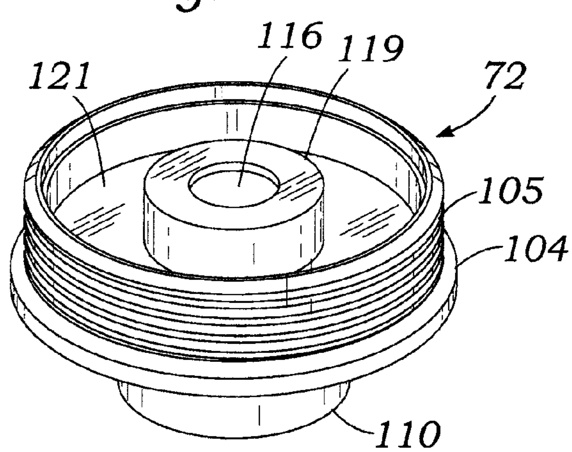


Fig. 15



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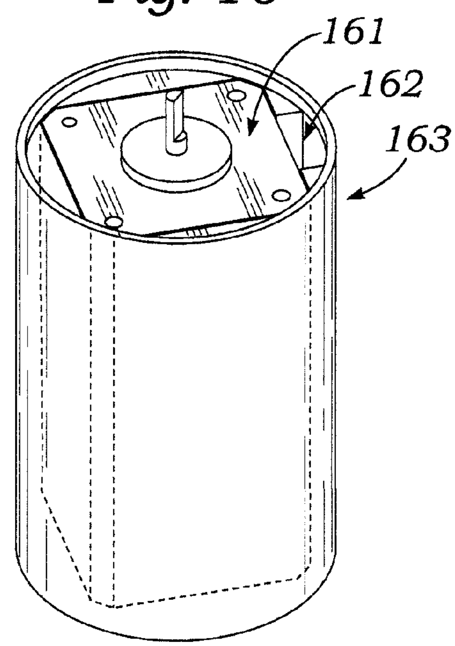


Fig. 19

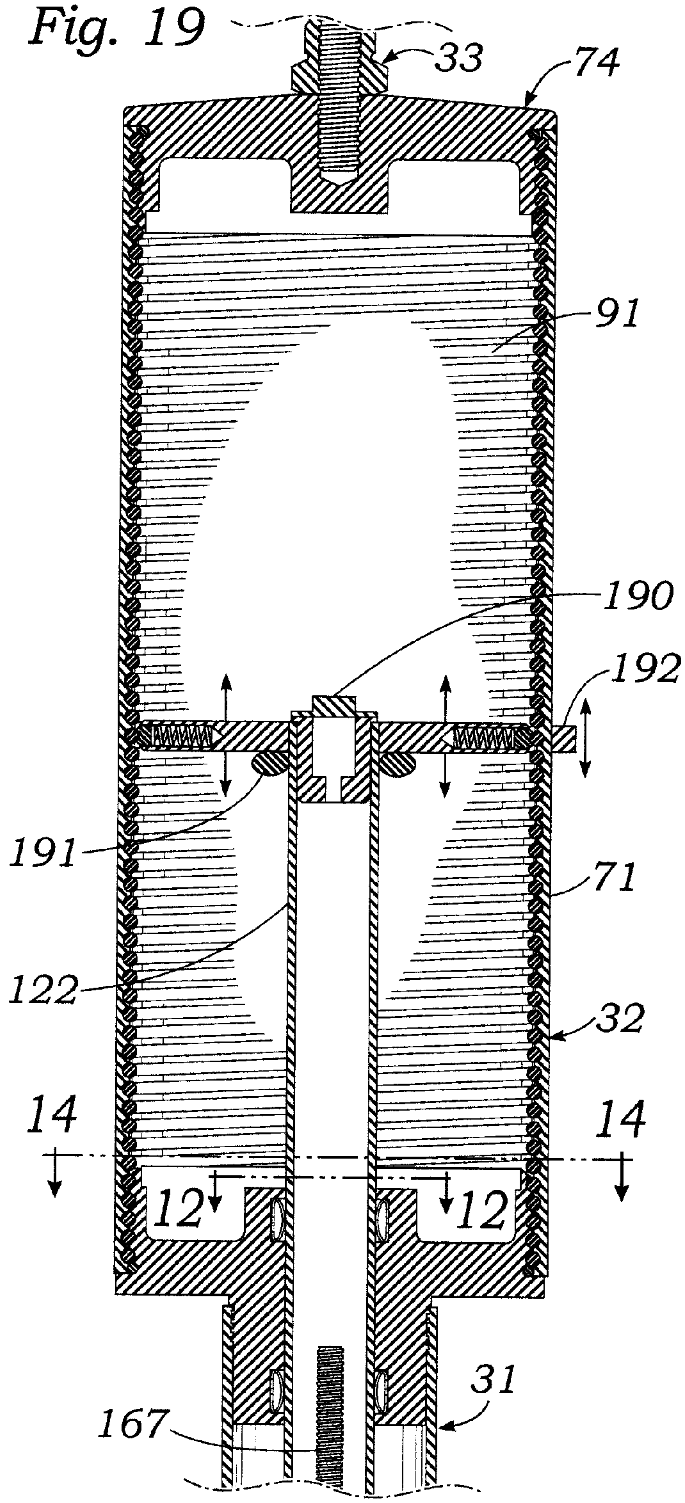
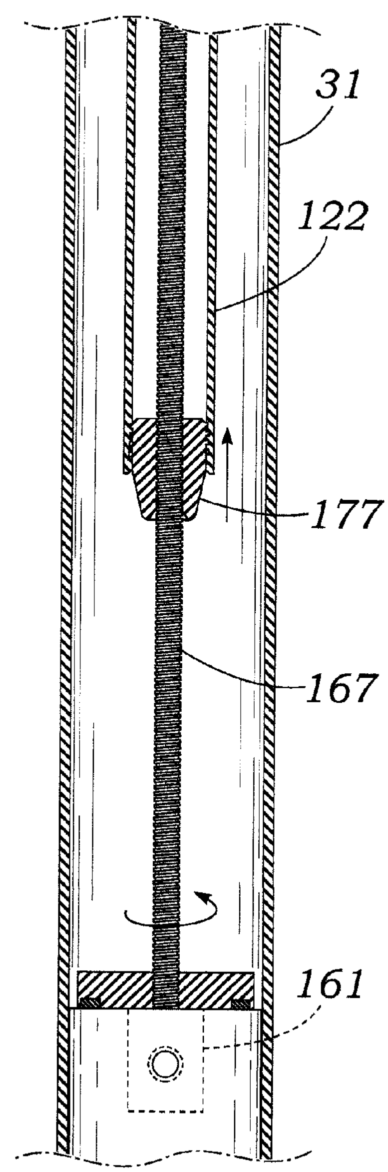


Fig. 20



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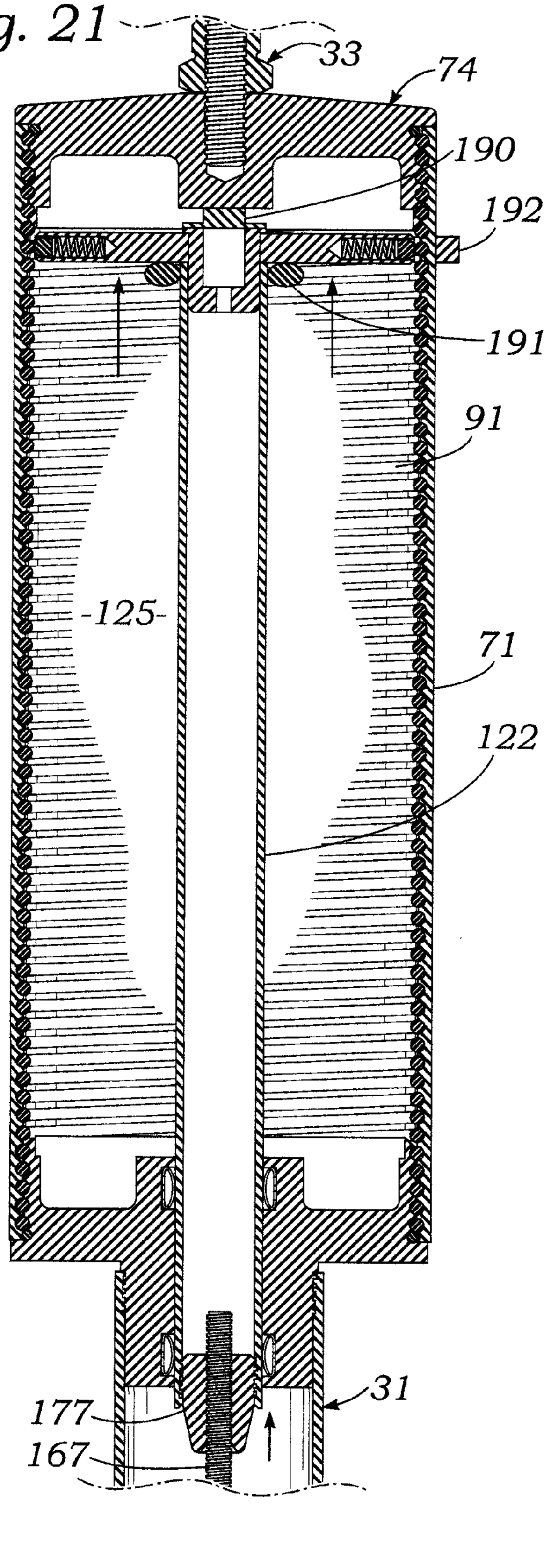


Fig. 22

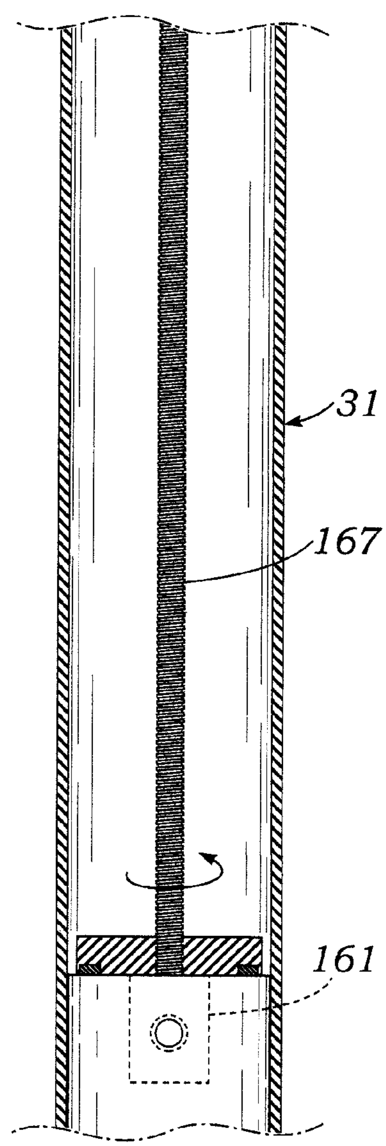
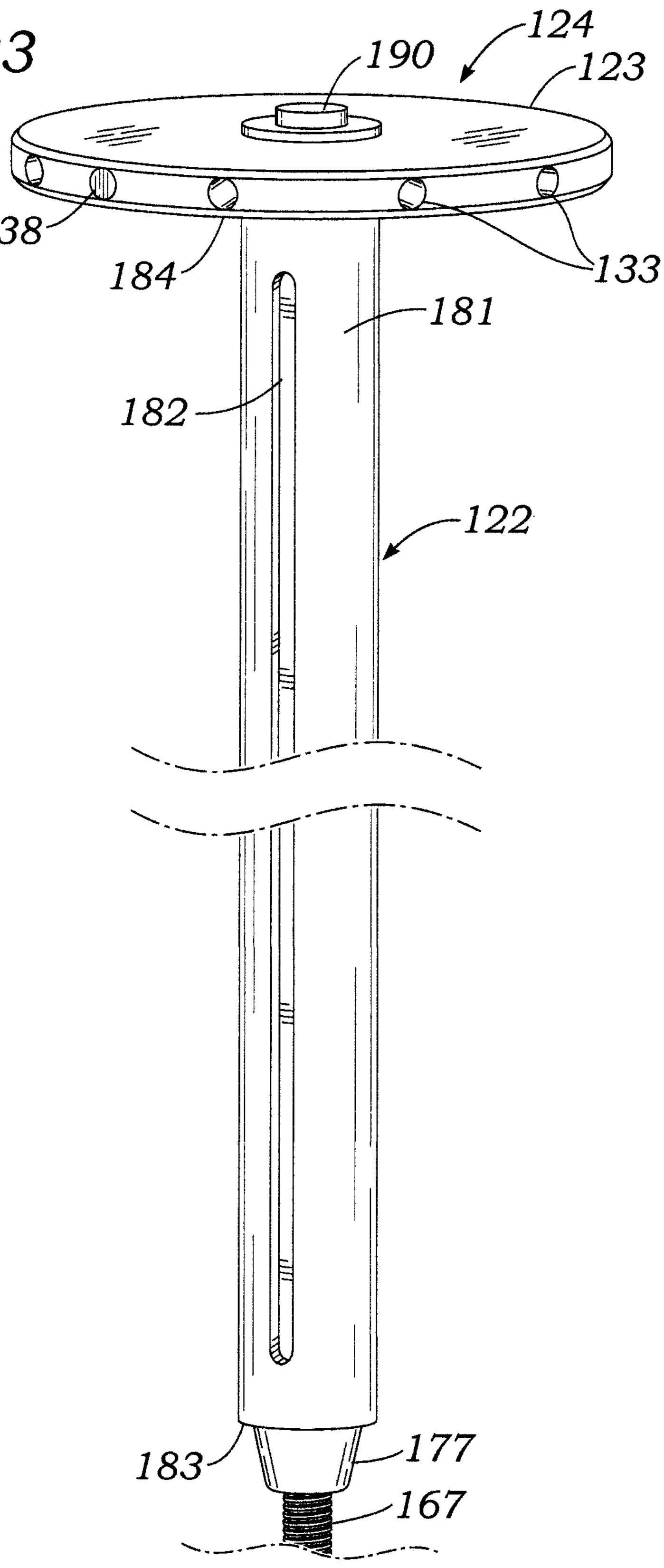


Fig. 23



RAPID TUNING FREQUENCY ADJUSTABLE MOBILE HF COMMUNICATION ANTENNA

BACKGROUND OF THE INVENTION

A. Field of the Invention

The present invention relates to antennas used to transmit and receive high frequency (HF) radio signals in the approximate range of 2 MHZ to 30 MHZ. More particularly, the invention relates to an HF monopole antenna which is attachable to a motor vehicle and which is rapidly tunable to maximize efficiency of transmitting and receiving radio signals at different selected frequencies contained in a relatively wide band.

B. Description of Background Art

Two-way radio communications between locations spaced apart at substantial distances, e.g., tens, hundreds or thousands of miles apart cannot utilize direct line-of-sight paths, because of the curvature of the earth's surface. Therefore, such radio communications use radio frequency signals which operate in a high frequency range, e.g., 2 MHZ to 30 MHZ, because radio signals in the HF range are reflected from the earth's ionosphere. Thus, HF radio signals can be transmitted obliquely upwards towards the ionosphere, and bounced back towards the earth beyond the visual horizon Signals which are reflected from the ionosphere and impinge the earth's surface can also be reflected back towards the ionosphere. In this way, multiple consecutive reflections of signals between the ground and the ionosphere can provide an effective means of transmitting HF signals over long distances. The ionosphere is electrically conductive and hence, effective in reflecting radio signals because of the presence of charged particles consisting of positively charged gas molecules and electrons which have been stripped from neutral molecules by impacting particles or energetic photons.

Because the ionized particles of atmospheric gases in the ionosphere are created largely by radiation from the sun, the concentration of ionized particles varies widely on a daily basis. As can be readily understood, the production of ionized particles overhead during daylight is greater than during nighttime. However, the re-combination of ions to form neutral atoms to thus decrease the concentration of ions depends on many variables, such as upper atmosphere winds. Moreover, in addition to diurnal variation in ion concentrations in the atmosphere, a variation in the sun's output of protons, which can be substantial, causes the ion concentration in the ionosphere to vary in unpredictable ways.

It is an observed and theoretically understand fact that the reflectivity of radio signals from the ionosphere depends both on the concentration of ions in the ionosphere, and upon the frequency of HF radio signals which are incident upon the ionosphere. Therefore, as is well know to HAM radio operators, as well as government agencies such as U.S. military services which communicate via HF radio signals, that it is often necessary to adjust the frequency of transmitted HF signals to values which are most effectively reflected from the ionosphere, to maximize the strength of a radio signal received at a distant location.

In addition to temporal variations of the reflectivity of the ionosphere which make adjustability of HF radio signal frequencies desirable there are spatial variations. Thus, for example, the optimum frequency for most effectively bouncing a transmitted signal from the ionosphere from a transmitter to a receiver station due North of the transmitter may differ from the optimum frequency for transmitting a signal to a receiver located West of the transmitter.

There are other reasons why it would be desirable to provide a HF communication link with frequency adjustability. For example, it is sometimes required that a fixed command and control site base station transmit different messages to different remote fixed or mobile receivers. Thus, by sending a sequence of messages, each at a different pre-selected frequency, a different message can be sent from a central command and control site to different intended recipients. Moreover, an operator at either a base station or a remote site can adjust the frequency of a transmitted radio signal and inquire of the distant recipient which frequencies provide the strongest received signals.

Also, it is possible to enhance the security of a radio frequency signal transmission by a technique known as frequency-hopping, in which information such as a voice communication message or a data stream is partitioned or time divided into a sequence of packets, each of which is sent sequentially at a different RF-carrier frequency.

In U.S. Pat. Nos. 6,275,195 and 6,496,154, the present inventor disclosed a frequency adjustable mobile monopole antenna that uses a circular shorting disk which is slidably moved by a motor-driven lead screw within the bore of a solenoidal loading coil disposed between a base mast and radiating whip section of a mobile monopole antenna. By moving the shorting disk up or down to contact and short-out a larger or smaller number of the coil turns, the inductance of the loading coil can be reduced or increased to cause the antenna to resonate at higher or lower selected frequencies. The disclosed frequency adjustable antenna has proven to be highly effective in performing its intended task of providing a frequency adjustable mobile antenna which can be reliably tuned by remote motor command signals to adjust the inductance of the loading coil to values which optimize transmission and reception efficiency over a wide band of frequencies. However, a need has remained for an adjustable frequency mobile monopole communication antenna which can be very rapidly tuned to thus meet greater speed-demanding applications such as frequency-hopping mentioned above. The present invention was motivated at least in part by this received need.

OBJECTS OF THE INVENTION

An object of the present invention is to provide a rapid tuning frequency adjustable mobile communication antenna which enables the antenna to efficiently transmit and receive radio signals over a relative wide range of selectable frequencies, particularly in the high frequency (HF) band between 2 MHz and 30 MHz.

Another object of the invention is to provide a rapid tuning frequency adjustable mobile HF communication antenna that is a linear monopole type and includes a vertically aligned assembly which has a lower electrically conductive mast section, an adjustable inductance loading coil section electrically connected to the upper end of the mast section, and an upper radiating whip section electrically connected to the upper end of the loading coil section, the loading coil section including a solenoidal coil which has an inductance that may be rapidly varied between precisely pre-determined values.

Another object of the invention is to provide a rapid tuning frequency adjustable mobile HF communication antenna which has an elongated solenoidal loading coil that has disposed through its bore a circular contactor disk which electrically contacts inner conductive surfaces of the coil wire turns and is supported at the upper end of a longitudinally movable carrier shaft that is in electrically conductive contact with the lower end lead of the coil, thus enabling the carrier shaft to move the coil contactor disk to precisely determined longitudinal locations to thereby short-out lower turns of an adjustable member of lower coil turns to thus reduce the inductance of the coil to precisely determined values.

Another object of the invention is to provide a rapid tuning frequency adjustable mobile HF communication antenna which has a linearly actuatable loading coil shorting disk which is made of an electrically conductive material, the disk having protruding radially inwardly from an outer longitudinally disposed circumferential rim thereof a plurality of circumferentially spaced apart, radially inwardly disposed cylindrical cavities each holding a silver plated steel contactor ball and an elongated electrically conductive compression spring which urges the ball radially outwards into contact with inner sides of loading coil turns.

Another object of the invention is to provide a rapid tuning frequency adjustable mobile HF communication antenna which has a solenoidal loading coil having disposed within its bore a shorting disk that is supported by an axially rearwardly disposed conductive carrier shaft which is rapidly extendable and retractable within the bore by means of a lead screw driven by a rotary stepper motor operated in a closed loop servo mode.

Various other objects and advantages of the present invention, and its most novel features, will become apparent to those skilled in the art by perusing the accompanying specification, drawings and claims.

It is to be understood that although the invention disclosed herein is fully capable of achieving the objects and providing the advantages described, the characteristics of the invention described herein are merely illustrative of the preferred embodiments. Accordingly, I do not intend that the scope of my exclusive rights and privileges in the invention be limited to details of the embodiments described. I do intend that equivalents, adaptations and modifications of the invention reasonably inferable from the description contained herein be included within the scope of the invention as defined by the appended claims.

SUMMARY OF THE INVENTION

Briefly stated, the present invention comprehends a Rapid Tuning Frequency Adjustable Mobile High Frequency (HF) Radio Communication Antenna for use with radio transceivers, particularly those used in motor vehicles. The antenna according to the present invention is a monopole type, sometimes referred to as a Marconi antenna, that has a vertically elongated body which is intended to be used in a vertical orientation to transmit and receive vertically polarized radio frequency signals in the approximate range of 2 MHz to 30 MHz.

The antenna according to the present invention includes a lower electrically conductive hollow tubular mast section which has at the lower end thereof a mounting bracket that is electrically isolated from the mast, and fastenable to a support structure such as a vehicle or bumper which serves as ground plane. The mounting bracket includes a plate which has an electrical insulated eyelet bushing disposed through its thickness dimension. The eyelet bushing has disposed through its bore a feed wire which is electrically conductively connected at a proximal end to the mast and which is connectable at a distal end to the high potential terminal of a radio transceiver via the isolated center conductor of a flexible coaxial cable.

The antenna according to the present invention includes a longitudinally elongated cylindrically-shaped hollow loading coil tube which is fixed to the upper end of the mast section in coaxial alignment therewith. The coil tube is made of an electrically non-conductive material such as polycarbonate and has formed in the inner cylindrical wall surface thereof an elongated helical groove. The groove holds conformally therewithin convolutions or turns of an electrically conductive loading coil wire which forms a uniform diameter, longitudinally elongated solenoidal coil.

The lower end of the loading coil is electrically conductively connected to a disk-shaped conductive metal base plug which is threadably received in electrically conductive contact with lower end turns of the loading coil, and fixedly attached to the coil tube. The lower end of the base plug is electrically conductively connected to the upper end of the mast, which supports the base plug.

The upper end of the coil tube supports therein an electrically conductive cap which is threadably inserted into and fixedly attached to the coil tube, in electrically conductive contact with upper end turns of the loading coil wire.

A conductive metal clamp which protrudes upwardly from the upper end of the coil tube cap receives the lower end of an elongated conductive flexible whip section of the antenna which protrudes upwardly from the center of the upper end cap. Thus constructed, the antenna according to the present invention comprises a vertically elongated electrically conductive structure which has a conductive mast, a solenoidal loading coil within an elongated insulated coil tube mounted on the upper end of the mast, and an antenna whip section which extends upwardly from the upper end of the coil tube, which is effective in transmitting and receiving vertically polarized electromagnetic radiation at radio frequencies.

The loading coil is electrically connected in series with the upper end of the antenna mast and the lower end of the whip, which is the primary radiating element of the antenna. As is known to those skilled in the art, adding inductance in series with the radiating element of a linear monopole antenna increases the effective electrical length of the antenna. Thus, for example, if the physical length of the antenna is 2.5 meters, which is equal to one quarter-wave of a 10-meter, 30-MHZ electromagnetic wave, the antenna is resonantly tuned, and operates at maximum efficiency for both transmitting and receiving 30-MHZ signals. However, the 2.5 meter length is much shorter than a quarter of a wave length of 2-MHZ signal, and thus is very inefficient in launching and receiving the lower frequency 2-MHZ signals. This is because at low frequencies the length of the antenna is substantially shorter than a quarter of a wave length, causing the antenna impedance to have a large negative reactive component, i.e., capacitive component.

By placing a loading coil in series with the monopole antenna, the positive reactance of the inductance of the coil opposes the negative capacitive reactance of the radiating element of the antenna, thus decreasing the magnitude of the reactive component of the antenna input impedance and thereby increasing the effective electrical length of the antenna to a value greater than its physical length. By a suitable choice of the value of the inductance of the loading coil, the effective length of a monopole antenna can be increased to a value much closer to one-quarter of a wavelength of lower frequency signals, and thus increase the input impedance of the antenna to a value which more closely matches the output impedance of a radio transceiver connected to the antenna. Such impedance matching minimizes signal reflections and improves efficiency of launching and receiving lower frequency signals.

In the present inventor's U.S. Pat. Nos. 6,275,195 and 6,496,156, a monopole antenna was disclosed which included a vertically disposed loading coil longitudinally aligned with a lower conductive mast section and an upwardly protruding whip section. The antenna disclosed in the present inventor's above-cited patents included a commutator or coil contactor which contacted the inner surfaces of the loading coil turns. The contactor was extendible by means of a motor-driven lead screw from a lower, maximum inductance position at which the commutator contacted the lowest turns of the loading coil, where the inductance of the loading coil was a maximum for tuning the antenna to a low frequency, and extendable to an upper limit position. In the upper limit position, an electrically conductive, shorting path was established between lower coils at the lower end of the loading coil and upper coil turns or convolutions located near the upper end of the loading coil. Thus, with the coil contactor extended to an upper position, the lower turns of the loading were shorted out. This shorting action reduced the value of the inductance in series with the mast and whip sections of the antenna, thus enabling the operating frequency of the antenna to be adjusted to higher values.

The presently disclosed frequency adjustable antenna has a structure and function which are similar to the present inventor's prior-disclosed frequency adjustable antenna. However, the presently disclosed frequency adjustable antenna has novel structural and functional characteristics which enable the antenna loading coil to transition between precisely controllable positions at very rapid rates.

The rapid and precise positioning of the coil contactor is facilitated by a novel coil contactor disk which is mounted to the upper end of a tubular carrier or actuator shaft. The coil contactor disk includes a plurality of circumferentially spaced apart, radially disposed cavities, each of which holds a silver plated steel contactor ball which is biased radially outwards by a conductive helical compression spring. The contact balls collectively form a very low electrical resistance path between the contactor disk and the inner conductive surfaces of a longitudinally disposed solenoidal loading coil wire. Moreover, the contact balls are free to rotate and thus present minimum resistance to rapid linear motion of the contactor disk within turns of the loading coil.

According to the present invention, a minimum electrical resistance and minimum frictional resistance, tubular support of the contact disk carrier shaft is provided by a pair of longitudinally spaced apart toroidally-shaped RF de-coupler rings which bear resiliently against the outer cylindrical wall surface of the longitudinally movable carrier shaft. Each decoupler ring is made from an elongated leaf spring which has an arcuately curved outer surface. The leaf spring is bent into a toroidal shape to position the curved surfaces of the spring sections in electrically conductive, slidable contact with the outer wall surface of the carrier shaft.

According to the invention, rapid reciprocating upward and downward motion of the carrier shaft to thus rapidly position the coil contactor disk at precisely repeatable longitudinal locations within the loading coil is facilitated by a novel lead screw drive mechanism. The latter employs a permanent magnet stepper motor which has an integral shaft angle encoder that provides a feed-back signal which enables the stepper motor to be operated in a closed-loop servo motor mode. In this mode, positioning accuracy and speed are increased and motor drive power requirements are decreased, from those of a stepper motor used in a customary open-loop mode.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a front elevation view of a Rapid Tuning Frequency Adjustable Mobile HF Communication Antenna according to the present invention.

FIG. **2** is an exploded longitudinal sectional view of the antenna of FIG. **1**.

FIG. **3** is a fragmentary sectional view of the antenna of FIGS. **1** and **2**, on an enlarged scale, showing an upper part of the antenna.

FIG. **4** is a fragmentary sectional view of the antenna of FIGS. **1** and **2** on an enlarged scale, showing a lower part of the antenna.

FIG. **5** is a fragmentary view of the antenna of FIGS. **1** and **2**, showing an antenna whip coupler component of the antenna.

FIG. **6** is a fragmentary sectional view of the antenna of FIG. **3** on an enlarged scale, showing a lower part of a coil section of the antenna.

FIG. **7** is a fragmentary sectional view of the antenna of FIG. **3**, showing an upper part of a loading coil section of the antenna.

FIG. **8** is an upper end elevation view of a coil contactor disk part of the antenna of FIG. **2**.

FIG. **9** is a side elevation view of the coil contactor disk of FIG. **8**.

FIG. **10** is a fragmentary sectional view of the antenna of FIG. **3** on an enlarged scale, showing the coil contactor disk and loading coil thereof.

FIG. **11** is a fragmentary longitudinal sectional view of the antenna of FIGS. **3** and **6**, showing one of two RF decoupler rings of the antenna with the inner circumferential surface of the ring in resilient, longitudinally slidable contact with the outer surface of a conductive carrier shaft which supports at the upper end thereof the coil contactor disk of FIGS. **8** and **9**.

FIG. **12** is a transverse sectional view of the decoupler ring and carrier shaft of FIGS. **6** and **11**.

FIG. **13** is an enlarged lineal sectional view of a spring strip from which the decoupler ring of FIGS. **11** and **12** is formed.

FIG. **14** is an upper plan view of a lower end cap part of the antenna of FIG. **2**, showing a decoupler ring of FIGS. **11-13** installed in the lower end cap.

FIG. **15** is an upper perspective view of the end cap of FIG. **14**.

FIG. **16** is a perspective view of a motor housing of the antenna of FIG. **2**.

FIG. **17** is an upper plan view of the motor housing of FIG. **16**.

FIG. **18** is a fragmentary view of the antenna of FIGS. **2** and **4**, showing a lead screw coupler and lead screw of the antenna.

FIG. **19** is a partly broken away view showing the coil tube contactor disk of the antenna in an intermediate, longitudinal position that has an intermediate inductance.

FIG. **20** is a fragmentary view of the mast, lead screw, follower nut and coil contactor support shaft for the configuration of FIG. **19**.

FIG. **21** is a partly broken away view showing the coil contactor disk at a fully extended, minimum inductance position.

FIG. **22** is a fragmentary view of the mast and lead screw for the configuration of FIG. **21**.

FIG. **23** is a fragmentary view of the antenna of FIG. **2** showing a coil contactor thereof.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIGS. **1-23** illustrate the structure and function of a rapid tuning frequency adjustable mobile HF communication antenna according to the present invention.

Referring first to FIG. **1**, it may be seen that a rapid tuning frequency adjustable mobile HF communication antenna **30** according to the present invention has generally the shape of a straight, vertically elongated tubular body that consists of a coaxially aligned, vertical stack of circular cross-section cylindrically-shaped sections. The sections of antenna **30** include a bottom cylindrically-shaped tubular mast section **31** which has a diameter of about 2.5 inches and a length of about 2¼ feet. The mast section **31** has attached coaxially to its upper end an axially aligned coil tube section **32**, which has a diameter of about 5½ inches, and a length of about 13 inches.

Antenna **30** includes a whip section **33** which has an elongated flexible whip antenna rod **34** which has a diameter of about ⅛ inch that extends perpendicularly upwards from the center of a conductive upper end cap **74** of the coil tube section **32**. Whip antenna **34** is made of a conductive metal, and typically has a length which is selected to resonate at a particular radio frequency. In the present case, antenna **30** is intended to be used as a monopole type antenna that extends vertically upwards from a ground plane. The resonant length of monopole whip is ¼ of a wavelength. Thus, for operation at 30 MHz, e.g., at a wavelength of 1 meter, whip **34** would have a length of about 2.5 meters, i.e., about 8 feet.

As shown in FIGS. **1**, **2** and **4**, frequency adjustable antenna **30** according to the present invention includes a mounting assembly **40** for mounting the antenna to a structural component of a vehicle such as a bumper. The mounting assembly **40** has a bracket **41** which includes a flat rectangular metal plate **42** that has through its thickness dimension a vertically disposed bolt hole **43**.

As shown in FIGS. **2** and **4**, mounting assembly **40** for attaching the lower end of tubular mast section **31** in an upstanding orientation to a structural component of a vehicle includes a cylindrically-shaped mast mounting plug **44**. Mast mounting plug **44** has an upper elongated cylindrically-shaped body section **45** which is slipped upwardly into the bore **46** of tubular mast section **31**. Upward travel of mounting plug **44** into bore **46** of mast tube **31** is limited by a thin, enlarged diameter annular base flange **47** located at the lower end of the mounting plug. Mounting plug **44** is secured to mast tube section **31** by screws **48** inserted through holes **49** disposed radially through the wall **50** of the mast section tube, and tightened into aligned threaded holes **51** which are disposed radially inwardly into body **45** of the plug from its outer cylindrical wall surface **52**.

As shown in FIGS. **2** and **4**, mast base mounting plug **44** preferably has a relatively large diameter central coaxial weight-reducing bore **53** which is disposed downwardly into the body **54** of the plug from its upper circular end face **54**.

As is also shown in FIGS. **2** and **4**, mast base mounting plug **44** has extending upwardly into body **45** from lower circular end face **55** thereof a coaxially centrally located, threaded mounting bolt hole **56**.

Referring still to FIGS. **2** and **4**, it may be seen that the body **45** of mounting base plug **44** has formed in the outer cylindrical wall surface **52** thereof a generally semi-circular cross-section longitudinally disposed groove **57** which extends the entire length of the plug and thus penetrates upper and lower end faces **54** and **55** of the plug. Groove **57** is provided to receive a motor controller cable **58**.

As shown in FIGS. **2** and **4**, mounting assembly **40** of mast section **31** includes lower and upper insulating washers **59**, **60** which are located below and above bracket plate **42** of bracket **41**, with central coaxial bores of the washers axially aligned with bolt hole **43** through the bracket plate. A flanged insulated bushing **61** is inserted downwardly through the aligned bores of upper insulating washer **60**, bracket bolt hole **43**, and lower insulating washer **61**. Mast section **31** is secured to bracket **41** in electrically isolated relationship to the bracket by means of a conductive metal bolt or cap screw **62** which is inserted upwardly through lower insulating washer, through bracket bolt hole **43**, through insulating flange bushing **61** and threadably tightened into threaded mounting bolt bore **56** that extends upwardly into body **45** of mounting plug **44** from the lower end face **55** of the plug body.

As may be understood by referring to FIG. **4**, mast section **31** of antenna **30** is electrically interconnected with a radio transceiver (not shown) by a coaxial cable **63** which has a central conductor **64** terminated by a conductive metal eyelet **65** that is secured between lower insulator **59** and bolt head **67** in electrically conductive contact with the bolt head. Coaxial cable **63** also has an outer flexible braided conductive metal shield lead **68** which is secured in electrically conductive contact to conductive metal bracket plate **42** by means of a screw **69** which is inserted through a conductive metal eyelet **70** and threadably tightened into a threaded bore **71** in the bracket plate.

Referring now to FIGS. **1-3**, it may be seen that coil tube section **32** of antenna **30** includes a longitudinally elongated, cylindrically-shaped tubular coil housing **71**. Coil tube housing **71** is made of a durable, high-dielectric strength material such as polycarbonate plastic. As shown in FIGS. **2** and **6**, coil tube housing **71** is mounted to the upper end of tubular mast section **31**, in coaxial alignment therewith, by means of a metal base plug **72** which fits coaxially within the lower end opening **73** of the coil tube housing **71**, and coaxially over the upper end of the mast section.

As shown in FIGS. **1-3** and **7**, antenna **30** includes a conductive metal cap **74** of antenna fits coaxially within the upper end opening **75** of coil tube housing **71**. Cap **74** is provided with a coaxial centrally located blind threaded bore **76** that extends downwardly into the cap from the upper surface **77** of the cap. Cap **74** has a lower skirt section **78** which has an external helical thread **79**. Cap **74** also has threadably fastened into blind bore **76** a threaded stud **76**A which is threadingly received upwardly into a plug **76**B which is in turn received in the lower fixed part **81** of a fold-over coupler **80**.

As shown in FIG. **5**, fold-over coupler **80** also includes an upper part **82** which is attached to lower part **80** by means of a transversely disposed bolt or screw **83**. Upper part **82** of coupler **80** has extending downwards from an upper end face **84** thereof a blind bore **85** for receiving the lower end **86** of elongated flexible antenna whip section **34**. Whip section **34** is retained in bore **85** by a clamp set screw **87**. Upper part **82** of coupler **80** is pivotable or foldable with respect to lower coupler part **81** to thus position whip section **34** at an orientation inclined or folded downwards from an upright vertical position, to avoid interference when a vehicle on which the antenna is mounted encounters reduced overhead clearance, such as when the vehicle is traveling through a tunnel. Pivotable motion between upper part **82** and lower part **81** of coupler **80** is enabled by a pivot joint **88** which includes a pivot pin consisting of screw **83** disposed laterally through holes **89**, **90** in the lower and upper coupler parts.

Referring now to FIGS. **2-3**, it may be seen that antenna **30** includes a longitudinally elongated solenoidal electrical coil **91** which is formed from a length of silver plated wire that is formed into a helix and pressed conformally into a longitudinally elongated helical groove **92** formed in the inner wall surface **93** of coil tube housing **71**. In an example embodiment of antenna **30**, coil **91** was wound from 12-gauge silver plated brass wire. Coil **91** has a lower end portion **94** which is in electrically conductive contact with metal base plug **72** at the lower end of coil tube housing **71**. Coil **91** also has an upper end portion **95** which is in electrically conductive contact with cap **74** at the upper end of the coil tube housing **71**.

As shown in FIG. **6**, base plug **72** is secured to the lower end of coil tube housing **71** in electrically conductive contact with lower end turns or convolutions **96** of coil **91**. Cap **74** is secured to the upper end of the coil tube housing **71** in electrically conductive contact with upper end turns **98** of the **91**, by similar means, as shown in FIGS. **6** and **7**.

Referring to FIG. **7**, it may be seen that metal cap **74** is preferably secured to coil tube housing **71** by means of external helical threads **99** in the outer cylindrical surface **100** of a lower reduced diameter, downwardly depending portion **101** of cap **74**. The threads **99** are threadingly received in a helical groove **102** located between upper end turns **98** of coil **91**, which protrude radially inwardly of the inner cylindrical wall surface **93** of the coil tube housing.

Similarly, as shown in FIG. **6**, metal base plug **72** of antenna **30** is provided with external helical threads **104** in the outer cylindrical wall surface **105** of a reduced diameter, upwardly depending upper portion **106** of the base plug. The threads **104** are threadingly received in a lower part of helical groove **102** located between lower end turns **96** of coil **91**, which protrude radially inwardly of the inner cylindrical wall surface **93** of the coil tube housing.

As, shown in FIG. **6**, base plug **72** has protruding downwardly from the lower circular face **108** of the upper cylindrical cap-shaped end portion **109** thereof a tubular reduced diameter, cylindrically-shaped neck section **110**. Neck section **110** is coaxially aligned with the upper large diameter end portion **109** of base plug **72**, and has formed in the outer cylindrical wall surface **111** of the lower neck section a longitudinally disposed, helical external thread **112**. As shown in FIG. **6**, lower threaded neck section **110** of coil base plug **72** is threadably received in an internal helical thread **113** formed in the inner cylindrical wall surface **114** of mast tube **31** which extends downwardly from its upper transverse annular end wall **115**.

Referring still to FIG. **6**, it may be seen that coil tube base plug **72** has disposed through its length a central circular cross-section coaxial bore **116**. Bore **116** extends longitudinally through base plug **72** from a lower transverse end face **117** thereof to an upper-transverse annular end face **118** of the base plug. As shown in FIG. **6**, the upper transverse annular end face **118** of coil base plug **72** which is penetrated by bore **116** is located at the upper end of a reduced diameter upper neck section **119** that extends upwardly from the upper surface **120** of the circular disk-shaped base **121** of the base plug. As will be described below, coaxial bore **116** through coil tube base plug is provided to longitudinally, slidably hold a tubular carrier shaft **122** which supports at its upper end a circular disk-shaped coil contactor disk **123** of a coil contactor **124**.

FIGS. **2**, **3** and **8-10** illustrate the structure and function of novel coil contactor **124** according to the present invention. The coil contactor **124** includes coil contactor disk **123** which is longitudinally movable in electrically conductive contact with inner surfaces of coil wire **97** in coil tube housing **71**, thus shorting out an adjustable number of lower coil turns to thereby lower the inductance presented in series between mast **31** and cap **74**, in a manner which will now be described.

As may be understood best by referring to FIGS. **3** and **8-10**, circular disk-shaped coil contactor disk **123** of antenna **30** fits coaxially within a longitudinally disposed, central coaxial bore **125** through coil **91** in tube housing **71**. Coil contactor disk **123**, which is made of an electrically conductive material such as aluminum, longitudinally slidably contacts the inner circumferential surface **126** of wire turns **127** of coil **91**.

As shown in FIGS. **8-10**, coil contactor disk **123** includes a body **128** which has the shape of a thin, uniform thickness circular disk. Body **128** of contactor disk **123** is preferably made of a light weight, electrically conductive material such as aluminum. As shown in FIGS. **8** and **9**, body **128** has flat, parallel upper and lower faces **129**, **130**, a longitudinally disposed, circular band-shaped outer circumferential edge wall **131** which is disposed perpendicularly between the upper and lower faces.

As shown in FIGS. **8** and **9**, body **128** of contactor disk **123** has extending radially inwardly from outer circumferential edge wall **131** thereof a sequence of cylindrically-shaped cavities **132** which are spaced circumferentially apart at equal intervals. Although the number, depth, diameter and spacing of cavities **132** is a matter of design choice, an example embodiment of contactor disk **123** tested by the present inventor had a diameter of 4¾ inches, and had 12 cavities **132** each having a diameter of about 0.257 inch and a depth of about 1 inch which were spaced apart at 30-degree intervals on the outer circumferential edge wall **131** of circular disk body **128**.

As shown in FIGS. **8** and **10**, each cavity **132** holds radially slidably therewithin a radially disposed, open-coil helical compression spring **133**. Each compression spring **133** is made of an electrically conductive material such as silver plated brass, and presses resiliently in a radially outwardly direction against a silver plated steel coil contactor ball **134** which has a diameter slightly less than diameter of cavity **132**, i.e., 0.250 inch and thus is radially movable with the cavity.

As may be understood by referring to FIGS. **3** and **10**, the novel construction of contactor disk **123** enables it to move longitudinally within coil **91** with coil contactor balls **134** in rolling electrically conductive contact with inner circumferential surface **126** of coil turns **127**, thus providing a rolling electrically conductive contact between contactor disk **123** and coil **91** which has very low electrical and frictional resistances.

As shown in FIG. **8**, coil contactor disk **123** preferably has through its thickness dimension a series of lightening holes to reduce the weight and hence inertia of the disk. Thus, for example, in the example embodiment of contactor disk **123** shown in FIG. **8**, body **128** of the contactor disk had an outer circle of twelve 0.625-inch diameter circular outer lightening holes **135** spaced apart at 30-degree intervals. The example embodiment of coil contactor disk **123** shown in FIG. **8** also had an inner circle of nine 0.500-inch diameter circular inner lightening holes **136**, which were located adjacent to a central circular coaxial shaft bore **137** through disk body **128**.

As shown in FIGS. **8** and **9**, coil contactor disk **123** preferably includes an indicator component consisting of a small cylindrically-shaped permanent magnet **138** which is held in a shallow cylindrically-shaped cavity **135** that is located between a pair of ball-and-spring cavities **132**. The function of indicator magnet **138** is described below.

As shown in FIGS. **2-4**, **6** and **9**, a central coaxial shaft bore **142** through coil contactor disk **137** receives therein a cylindrical cup-shaped fastener insert **139** which is insertably received and fixed in the upper opening of bore **143** through tubular support or carrier shaft **122**.

As may be seen by referring to FIGS. **2-4** and **6**, support shaft **122** of contactor disk **123** is positioned coaxially within bore **144** of mast tube section **131**, and is reciprocally movable up and down within the bore.

Referring now to FIG. **6**, it may be seen that base plug **72** of antenna **30** includes a pair of longitudinally spaced apart, upper and lower RF decoupler rings **145**U and **145**L. The function of RF decoupler rings **145**U, **145**L is to provide a low electrical resistance, low sliding friction contact between the body of base plug **72**, which is in electrically conductive contact with the upper end of conductive mast tube **31**, and the outer cylindrical wall surface **156** of support carrier tube **122** of coil contactor disk **123**. By providing this low electrical resistance path, RF decoupler rings **145**U, **145**L provide a low resistance shorting path between the contactor disk **123** and the lower end lead of loading coil **91**. By providing this lower electrical resistance shorting path, turns of coil **91** located below the coil contactor disk **123** are shorted out or "decoupled," thus reducing the inductance between the antenna whip **34** connected to the upper end lead of the coil, and the mast **31** connected to the lower end of the coil.

As shown in FIGS. **6** and **11**-**13**, each decoupler ring **145** is formed from an elongated rectangular metal strip **146** which has upper and lower straight, parallel edges **147**, **148** that have cut perpendicularly inwards at equal longitudinal intervals thin, shallow rectangularly-shaped notches **149**, **150**, respectively. In an example embodiment of antenna **30**, metal strip **146** of de-coupler ring **145** was made of silver plated beryllium copper.

As shown in FIGS. **11**-**13**, the notches **149**, **150** enable the metal strip **146** to be bent into a series of laterally spaced apart rings **151** that have in a transverse cross-sectional view a lenticular shape with an arcuately curved convex outer surface **152**.

As shown in FIG. **12**, after metal strip **146** has been worked to form therein a series of lenticular rings **151**, the strip is bent into a toroid-like shape, with the arcuately curved convex surface **152** of the ring lying on a circle inscribed within the cylinder defined by the outer bent base surface **153** of the strip. As shown in FIGS. **6**, **11**, **12** and **14**-**15**, toroidal ring-shaped decoupler contactor rings **145**U, **145**L are then inserted into annular cavities **153**U, **153**L formed in the inner cylindrical wall surface **154** of upper and lower sections **155**, **156** of base plug **72**. In these locations the outer arcuately curved convex surface **152** of each ring slidingly contacts the outer surface **157** of coil contactor disk carrier shaft **122**.

FIGS. **2**-**4**, **6**, **17** and **18** illustrate structure and function of a rotary motor-driven linear actuator mechanism **160** for extending and retracting coil contactor disk **123** upwardly and downwardly within bore **125** through coil **91**. Upward and downward motion of the coil contactor disk **123** causes more or less turns of coil **91** to be shorted out, thus decreasing or increasing the inductance in series with mast **31** and antenna whip **34**. Decreasing or increasing the inductance in series with mast **31** and whip **34** enables antenna **30** to be tuned for optimum impedance matching with a radio transceiver at higher or lower relative operating frequencies, respectively.

As, shown in FIGS. **2**, **4**, and **16**-**18**, linear actuator mechanism **160** of coil contactor **124** includes a stepper motor **161**. Stepper motor **161** has generally the shape of a rectangular block, and is mounted within a rectangular block-shaped cavity **162** in a motor mount housing **163** which has the shape of a right circular cylinder. As shown in FIG. **4**, motor housing **163** holding motor **161** fits coaxially within bore **164** through mast section **31**, on top of mast mounting plug **44**. Motor mount housing **163** is made of an electrically non-conductive material such as a structural plastic to maintain electrical isolation between motor **161** and mast section **31**.

Motor **161** has protruding upwards from an upper transverse end face **165** thereof a rotary output shaft **166**. As shown in FIGS. **4** and **18**, motor shaft **161** is connected by a lead-screw coupler **168** to an elongated straight lead screw **167** which extends upwardly from motor **161** in axial alignment with the motor shaft. As shown in FIG. **14**, coupler **168** includes an upper short cylindrical disk-shaped part **169**, a lower elongated cylindrical section **170** which extends downwardly from the lower annular face of the upper disk section, and a bore **171** which extends through both upper and lower sections of the coupler. Coupler **168** has disposed radially inwardly into the outer cylindrical wall surface **172** of lower section **170** thereof an upper set screw **173** for tightening onto lead screw **167**, and a lower set screw **174** for tightening onto motor shaft **166**.

As shown in FIGS. **2** and **4**, motor controller cable **58** is connected at a proximal end thereof to rotary motor **161**, and is disposed through groove **57** through base plug **44** of mast section **31** to an electrical motor controller **175** (not shown) located external to antenna **30**.

In a preferred example embodiment of antenna **30** according to the present invention, motor **161** was a high pole-count, 2-phase permanent magnet stepper motor model number QCI-A17H-3S0061, which was obtained from Quicksilver Controls Inc., 712 Arrow Grand Circle, Covina Calif. 91722, USA. That motor includes a shaft angle encoder which provides a position feed back signal that is used by a controller, model number QCI-D2-IG-J to operate the motor in closed-loop, 2-phase, A-C servomotor mode, rather than in the conventional open-loop mode used to drive a stepper motor. The use of shaft angle position feedback to adjust the drive current of motor **161** in a closed loop mode enabled the lead screw **173** to be rotated at higher speeds to more precisely determinable angular positions than could be achieved using a stepper motor in an open-loop mode, and used less electrical power in operation.

In an example embodiment of antenna **30** using the above-described motor and motor drive electronics, the antenna was tunable over a frequency range from about 2 MHZ to about 30 MHZ, in which contactor disk travel was about 12 inches, in about 700 milliseconds. This extremely fast tuning rate facilitates operation of the antenna **30** in such applications as Frequency Hopping and Automatic Link Establishment (ALE).

According to the invention, the controller which provides drive currents to motor **161** preferably is programmable to enable a user of antenna **30** to select input commands to the controller which cause the motor to drive coil contactor disk **123** to a any one of a large number of pre-determined longitudinal positions within coil **91** that tune the antenna to a corresponding large number of discrete frequency channels in the range of 2-30 MHZ. In an example embodiment of antenna **30**, software used with the motor controller enabled the selection of 500 different frequency channels, and had the capability of being expanded to 2000 channels.

FIGS. **3**, **4** and **6** illustrate how controller **175** is used provide drive signals to motor **161** which enable coil contactor disk **123** to be positioned upwardly and downwardly rapidly within bore **125** of coil **91** to thus rapidly decrease or increase the inductance of coil **91** in series with mast section **31** and antenna whip **34** to precisely adjustable values.

As shown in FIGS. **3**, **4** and **6**, tubular coil contactor disk support shaft **122** has threadably received in a lower internally threaded entrance section **176** of bore **143** through the support shaft a lead screw follower nut **177** which has the shape of an externally threaded plug shaped like an inverted frustum of a cone. Lead screw follow nut has disposed though its length a central threaded bore **17** which threadingly receives the upper end of lead screw **167**.

Antenna **30** preferably has a construction which prevents carrier shaft **122** and ball contactor disk **123** from rotating in response to torques exerted on lead screw follower nut **177** when the lead screw is rotated by motor **161**. Thus, as shown in FIGS. **6** and **23**, carrier shaft **122** has formed in its outer cylindrical wall surface **181** an elongated shallow, U-shaped groove **182** which extends from a short distance above lower end face **183** of the shaft to a short distance below upper end face **184** of the carrier shaft. Groove **182** receives resiliently therein a ball **185** which is urged radially inwardly by an open-coil helical compression spring **186** disposed through radial bore **187** through mast section **31**, and an aligned radial bore **188** disposed through lower neck section **110** of coil tube housing **78**. Ball **185** and spring **186** are held in place by a set screw **189** threaded into bore **188**.

With motor shaft **179** rotated to a maximum counterclockwise position, as viewed from above the upper end face **180** of lead screw **167**, carrier support shaft **122** of coil contactor disk **123** is retracted to a lower limit position, at which the inductance presented by coil **91** in series with mast section **31** and antenna whip **34** is a maximum value in an example embodiment of antenna, the inductance of coil **91** was about 350 microhenup.

As shown in FIGS. **19** and **20**, when motor **161** has received drive currents sufficient to rotate motor shaft **179** and lead screw **167** a sufficient number of turns in a clockwise sense, follower lead screw nut **177**, coil contactor disk support shaft **122**, and coil contactor disk **123** will be extended upwardly to, for example, a location midway through the length of bore **125** through coil **91**, as shown in FIG. **19**.

In intermediate longitudinal positions of contactor disk **123** within bore **125** of coil **92**, electrical contact is made between the contactor disk and one or more turns **127** of coil **91**, located at the same longitudinal position within bore **125** of coil **91** as coil contactor disk balls **134**. The coil contactor balls **124** are also in electrical contact with coil contactor disk carrier shaft **122**, which is in slidable electrical contact with decoupler rings **145**U and **145**L. Also, the decoupler rings **145**U, **145**L are in electrically conductive contact with the conductive body of base cap **74**, which is in turn in electrically conductive contact with lower turns **127** of coil **91**. Thus, as shown in FIG. **19**, when coil contactor disk **123** is located longitudinally midway within bore **125** of coil **91**, those turns **127** of coil **91** located between the coil contactor disk and plug **74** below the coil contactor disk are shunted by and hence shorted out by the low resistance electrical path descried above. Therefore, for the position of coil contactor disk **123** shown in FIG. **19**, the inductance between mast section **31** and antenna whip **34** is reduced to about one-half of the value of the inductance for the lower limit position of the coil contactor disk **123** shown in FIG. **3**. Also, the lower turns of coil **91** are shorted out, thus suppressing any harmonic currents which might otherwise be induced in the lower coil turns.

As shown in FIGS. **21** and **22**, when motor **161** has received for a sufficiently long period of time a clockwise drive signal, follower nut **177**, coil contactor disk support shaft **122** and coil contactor disk **123** will be extended upwardly to the upper limit of travel of the coil contactor disk. At this position, the coil contactor disk **123** shorts out substantially all of the turns **127** of coil **91**, thus reducing the inductance in series with mast section **31** and antenna whip **34** to a minimum value which approaches zero.

As shown in FIGS. **3**, **9**, and **21**, coil contactor **124** preferably includes a cylindrically-shaped rubber bumper **190** which protrudes coaxially upwards from the center of fastener plug **139** in coil contactor disk **23**.

As may be understood by referring to FIG. **21**, contact of the upper surface of bumper **190** with the lower surface of coil housing cap **174** at the upper travel limit of coil contactor support shaft **122** and coil contactor disk **123** causes the bumper to elastically deform, thus absorbing impact shock and returning elastically stored energy to the contactor disk, thus facilitating rapid reversal of upward motion of the contactor disk **123** to downward motion.

As shown in FIG. **3**, coil contactor **124** also preferably includes a resilient elastomeric O-ring **191** which fits coaxially over the upper end of contactor support shaft **122** which contacts the lower surface of coil contactor disk **123**.

As my be understood by referring to FIG. **3**, contact of the lower surface of O-ring **191** with the upper surface of coil assembly base cup **72** at the lower travel limit of coil contactor support shaft **122** and coil contactor disk **123** causes the O-ring to elastically deform, thus absorbing shock and returning elastically stored energy to the contactor disk, thus facilitating rapid reversal of downward motion of the coil contactor disk to upward motion.

FIGS. **3**, **19** and **21** illustrate how indicator magnet **138** mounted in the periphery of coil contactor disk **123** is used to provide an external visual indicator of the longitudinal position of the coil contactor disk within coil housing tube **71**. As shown in FIG. **3**, a small cylindrically-shaped permanent magnet **192** is placed on the outer surface **193** of coil housing tube **71**, in magnetic adherence to indicator magnet **138** within bore **125** of coil **91** inside the coil housing tube. Then, as shown in FIGS. **19** and **21**, as the coil contactor disk **123** is moved upwards or downwards within coil housing tube **71**, external indicator magnet **192** slides along the outer surface **193** of the coil housing tube magnetically adhered to internal indicator magnet **138**, thus indicating the longitudinal position of coil contactor disk **123** within the housing.

What is claimed is:

1. A frequency adjustable antenna for radio transceivers operable over a range of radio frequencies comprising;

a. a lower electrically conductive base mast section with a radio frequency connection thereto,

b. an elongated hollow cylindrical housing made of an electrically non-conductive material and having formed in an inner cylindrical wall surface thereof a longitudinally disposed helical groove,

c. an electrically conductive loading coil comprised of a conductor formed into longitudinally spaced apart convolutions comprising a helix of the same pitch as said helical groove in said housing, and fitting within said helical groove with an inner cylindrical surface of said helix located radially inward of said inner cylindrical wall surface of said housing, each of said coil convolutions having a radially inwardly located arcuately curved convex surface,

d. a base plug located at a lower end of said housing, sad base plug being in electrically conductive contact at a lower end thereof with said mast section and at an upper end thereof with a lower end of said coil,

e. a cap adapted to hold in electrical contact therewith an elongated conductive whip located at an upper end of said housing, said cap being in electrical conductive contact with an upper end of said coil,

f. an elongated conductive coil contactor support shaft located coaxially within said mast and said coil,

g. a coil contactor carried by and in electrically conductive contact with said conductive shaft, said coil contactor including a transversely disposed disk which has extending radially inwardly into a longitudinally disposed outer peripheral circumferential wall thereof at least at first pair of circumferentially spaced apart, radially disposed cavities, each of said cavities holding a radially movable electrically conductive contactor ball which is urged radially outwards by a compressed electrically conductive helical compression spring located within a said cavity between a said contactor ball and a transverse inner end of said cavity with sufficient force to maintain continuous rolling electrically conductively contact between a radially outwardly located surface of a said contactor ball a radially inwardly located arcuately curved convex surface of at least one of said coil convolutions when said coil contactor disk is moved longitudinally within the bore of said loading coil, said contactor balls having a diameter larger than longitudinal spacing between said convutions of said loading coil, said compression spring, contactor balls, and said convolutions of said loading coil each having an electrical conductivity at least as great as that of brass,

h. at least a first RF de-coupler ring which is located in said electrically conductive cylindrical base plug, said RF de-coupler ring bearing resiliently and slidably against the outer cylindrical wall surface of said shaft longitudinally slidably located within a bore through said base plug, and

I. an actuator for moving said conductive shaft and said coil contactor disk coaxially located within said bore of said loading coil longitudinally upward and downward to short out more or less coil turns in series with said whip and said mast, thereby decreasing or decreasing the inductance between said whip and said mast section to adjustably tune said antenna to higher or lower frequencies.

2. The frequency adjustable antenna of claim **1** wherein said coil convolutions are coaxial with said coil contactor disk.

3. The frequency adjustable antenna of claim **1** wherein said coil convolutions are coaxial with said cylindrical housing.

4. The frequency adjustable antenna of claim **3** wherein said base plug is coaxial with and projects upwardly from said mast section.

5. The frequency adjustable antenna of claim **4** wherein said housing is coaxial with and projects upwardly from said base plug.

6. The frequency adjustable antenna of claim **5** wherein said base plug is coaxial with said housing.

7. The frequency adjustable antenna of claim **6** wherein said conductive shaft carrying said coil contactor disk is guided coaxially within said mast by a guide opening in said base plug.

8. The frequency adjustable antenna of claim **1** wherein said mast is tubular, and wherein said actuator is a linear actuator which comprises in combination a reversible motor housed within a lower portion of said mast, a lead screw coupled to and protruding axially upward from a rotary output shaft of said motor, and an internally threaded follower nut secured to said conductive shaft, said lead screw threadingly engaging said follower nut.

9. The frequency adjustable antenna of claim **8** wherein said motor includes a shaft angle encoder.

10. The frequency adjustable antenna of claim **9** wherein said motor is supplied with drive currents from a closed-loop servo amplifier which includes as inputs a position command signal to position said coil contactor disk at a selected longitudinal position within said coil, and a shaft angle encoder feed-back signal.

11. The frequency adjustable antenna of claim **10** wherein said motor is further defined as a multi-pole, two-phase AC stepper motor.

12. The frequency adjustable antenna of claim **11** wherein said motor is driven in a four- quadrant, variable frequency servo loop.

13. The frequency adjustable antenna of claim **12** wherein electrical currents used to drive said motor are variable in frequency.

14. The frequency adjustable antenna of claim **13** wherein said drive currents are adjusted in response to continuous and periodic sampling of an error signal proportional to the difference between directed and actual positions of said motor shaft.

15. The frequency adjustable antenna of claim **1** wherein said first RF de-coupler ring is further defined as an electrically conductive annular ring-shaped spring, member comprised of a single longitudinally elongated rectangularly-shaped strip of resilient conductive material, upper opposed longitudinal edges of which are bent outwardly from the plane of the strip and thence axially inwardly towards a longitudinal center line of the strip to form two axially spaced apart rear, outer longitudinally disposed supporting band members, the inner, front surface of said strip continuous with said supporting band members being formed into an arcuately curved convex arched surface segmented into a plurality of longitudinally spaced apart arched tabs, said strip being bent into a ring-shaped loop having an axially disposed curvature axis coaxial with said conductive shaft to thereby arrange said tabs into an annular ring-shaped array having convex inner surfaces resiliently biased radially inwardly to contact an outer cylindrical surface of said conducive shaft.

16. The frequency adjustable antenna of claim **15** wherein said conductive material of said strip is further defined as being a beryllium copper alloy.

17. The frequency adjustable antenna of claim **15** wherein said first RF de-coupler ring is further defined as being located within a first annular groove located in a wall of said central coaxial bore through said base plug.

18. The frequency adjustable antenna of claim **17** further including a second RF de-coupler ring located within a second annular groove in said wall of said central coaxial bore through said base plug spaced axially from said first groove.

19. The frequency adjustable antenna of claim **1** further including an anti-rotation mechanism for preventing said shaft from rotating in response to torques transmitted to said shaft by said lead screw.

20. The frequency adjustable antenna of claim **19** wherein said anti-rotation mechanism includes in combination a longitudinally disposed groove in the outer surface of said shaft and an indexing member which protrudes into said groove from said base plug.

21. The frequency adjustable antenna of claim **20** wherein said indexing member is further defined as a ball biased radially inwardly into said groove by a spring.

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